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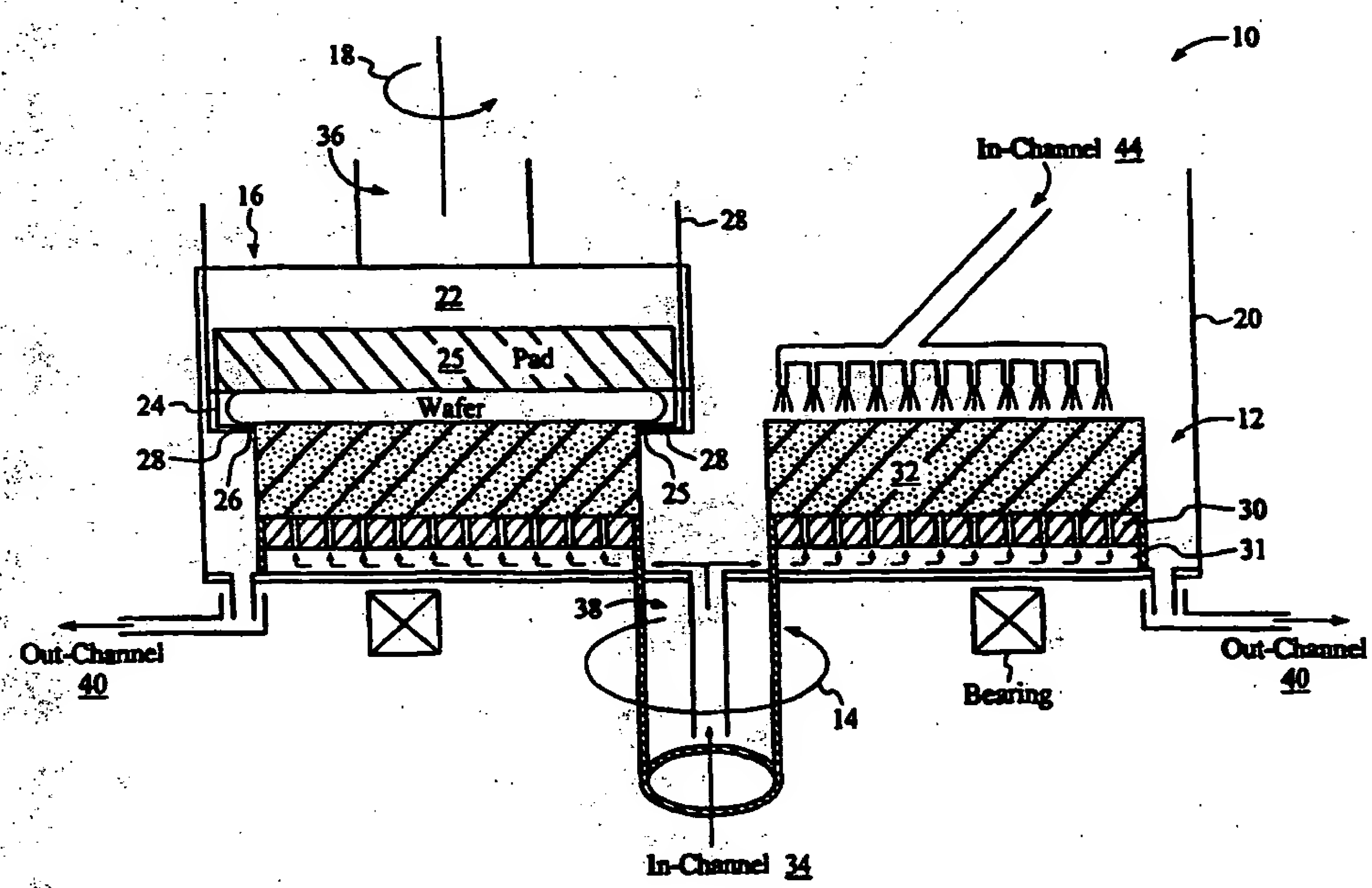

(57) Abstract

The present invention deposits a conductive material from an lectrolyte solution to a predetermined area of a wafer. The steps that are used when making this application include applying the conductive material t the predetermined area of the wafer using an electrolyte solution disposed on a surface of the wafer, when the wafer is disposed between a cathode and an anode, and preventing accumulation of the conductive material to areas other than the predetermined area by mechanically polishing the other areas while the c nductive material is being applied.

METHOD AND APPARATUS FOR ELECTROCHEMICAL MECHANICAL DEPOSITION

Background of the Invention

Field of the Invention

The present invention relates to a Method and Apparatus for Electrochemical Mechanical Deposition, and more particularly, to a method and apparatus that provides for both the deposition and polishing of a conductive material on a semiconductor wafer.

Background of the Invention

Metallization of semiconductor wafers, i.e. deposition of a layer of metal on the face of wafers over a barrier/seed layer of metal has important and broad application in the semiconductor industry. Conventionally, aluminum and other metals are deposited as one of many metal layers that make up a semiconductor chip. More recently, there is great interest in the deposition of copper for interconnects on semiconductor chips, since, as compared to aluminum, copper reduces electrical resistance and allows semiconductor chips using copper to run faster with less heat generation, resulting in a significant gain in chip capacity and efficiency.

Conformal thin film deposition of copper into deep submicron via holes and trenches is becoming more difficult in ULSI chip processing, especially when the feature sizes are decreasing below the 0.25 μm with aspect ratios of greater than 5 to 1. Common chemical vapor deposition and electroplating techniques have been used to fill these deep cavities etched into silicon substrates. These processes so far have yielded a very high cost and defect density for developing and integrating local interconnects for ULSI technology.

One of the factors that contributes to the high cost is the manner in which the conductive material, and particularly copper, is applied. Specifically, it is well known to apply certain contaminants, known as leveling agents, in the electrolyte solution that prevent or slow down the rate of deposition of the metal to the surface of the wafer substrate. Since these contaminants have a large size in comparison to the size of the typical via that needs to be filled, deposition of the metal on the surface of the wafer is, in part, prevented. This prevention, however, is achieved at the expense of adding contaminants to the electrolytic solution, which results, in part, in vias that do not have the desired conductive characteristics. In particular, the grain size of the deposited conductor, due to the use of such contaminants, is not as large as desired, which thereby results in quality problems for the resulting device, as well as increased expense due to significant annealing times that are subsequently required.

Further, the cost of achieving the desired structure, in which the conductive material exists in the via but not on the substrate surface, still requires separate deposition and polishing steps. After the conventional deposition of the metal using an anode, cathode and electrolytic solution containing metal as is known, there is then required a polishing step, which polishing step is, for high performance devices at the present time, typically a chemical-mechanical polishing step. While chemical mechanical

Figs. 1A and 1B illustrate a first embodiment of the invention;

Fig. 2 illustrates a second embodiment of the invention;

Fig. 3 illustrates a representative via to be filled with a conductor according to the invention: and

Figs. 4A - 4C illustrate a third embodiment of the invention.

Detailed Description of the Preferred Embodiments

The preferred embodiments of this invention will now be described. As noted above, conventional processing uses different equipment. at different times, in order to obtain conductive material within vias or at other desired locations on the surface of a semiconductor wafer that contains many different semiconductor chips, but not have the conductive material disposed at undesired locations. Accordingly, the equipment cost needed to manufacture a high quality semiconductor integrated circuit device can be exorbitant.

The present invention contemplates different embodiments which allow for the same device, termed a "electrochemical mechanical deposition apparatus", to be used to both deposit a conductive material, as well as then polish or reduce the rate of deposition of that conductive material. The "electrochemical mechanical deposition apparatus" can also be used to simultaneously deposit and/or polish the conductive material. While the present invention can be used with any conductive material or any workpiece suitable for plating, it is especially suited for use with copper as the conductor, and for use in the fabrication of ULSI integrated circuits having submicron features with large aspect ratios. In the various embodiments, the present invention uses conventional components, arranged in a unique manner, in order to achieve the functionalities described herein.

Figure 3 is first referred to in order to illustrate a portion of an integrated circuit chip that includes an area in which a via is to be formed. The via, as known in the semiconductor arts, being a conductive material that electrically connects different circuit layers together. As shown in Fig. 3, a via contains a conductor 2 that can connect a lower level conductive area 4 with an upper level conductive area 6, with insulative material 8 disposed therearound. Of course, it is understood that the present invention can operate upon any metal layer of a multi-layer integrated circuit chip.

Figs. 1A and 1B illustrate a first embodiment of the invention, which embodiment has two different modes of operation. In a first mode, a conductive metal, preferably copper, or other conductive material, is applied in vias and/or other desired areas using an electrolyte solution, while build-up of the conductive material on undesired areas is eliminated, or at least minimized, due to the mechanical polishing and/or electrolytic solution deprivation to top surface areas of the semiconductor wafer that is described hereinafter. In a second mode of operation, polishing of the wafer, using a conventional chemical mechanical polishing, can be performed using the same device, to the extent that such chemical mechanical polishing is needed. It is c ntemplated that, according to this embodiment of the invention, in most circumstances only the first mode of operation will be needed. The second mode of

the electrolyte up through the anode plate 30 and pad 32 using the in-channel 34. Alternatively, in-channel 44 can also be used to dispense the electrolyte directly down onto the surface of the pad 32.

The wafer head assembly 16 faces toward the mechanical pad assembly 12, and is pushed down with a controlled force. The wafer head assembly 16 rotates around axis 18 using a conventional motorized spindle 36, whereas the mechanical pad assembly 12 rotates around axis 14 using a conventional motorized spindle 38.

Proper drainage channels 40 provide a safe recycling or disposal of electrolyte. Thus, once the electrolyte is placed onto the pad 32 as described above, it can be drained via the drainage channels 40 to a resuscitating reservoir, also not shown, that can replenish and clean the electrolyte, thereby allowing re-use and being environmentally safe.

The inlet 44 can also be used to apply deionized water when operating in the second mode of the invention, as discussed hereinafter.

In operation according to the first mode of the invention, the apparatus 10 applies, using a power source, a negative potential to the cathode contact 28 and a positive potential to the anode 30. The electrolytic solution is introduced through one or both of the in-channels 34 and 44 to the surface of the mechanical polishing pad 32. When an electric current is established between the two electrodes, molecules of metals in electrolyte are ionized and deposited on the surface of the wafer, being attracted thereto by the cathode contact 28. While this is taking place, there is also performed a mechanical polishing using the mechanical pad assembly 12. This mechanical pad assembly 12 substantially prevents molecules of metals from becoming permanently deposited on surfaces of the wafer where such a deposit is undesired, due to the polishing or rubbing action of the mechanical pad 32. Thus, the contaminants or additives referred to above that are presently used to prevent or reduce such depositing are not needed, or alternatively, can be used in much smaller percentages. Accordingly, at the conclusion of the first mode of operation, metal is deposited in vias and the like where desired, and is substantially prevented from being deposited in undesired areas.

In a second mode of operation, a number of different conventional operations can be performed, depending upon the chemicals introduced via the in-channel 44. If chemical mechanical polishing is desired, a slurry can be introduced, although this specific mode of operation is not preferred since it increases the amount of impurities introduced into the apparatus fluid chamber substantially. In the preferred second mode of operation, the apparatus 10 can be used to buff polish the seed layer or be used as an Electro-polisher by reversing the current polarity (cathode and anode polarity). Further, the apparatus 10 can also be purged with M water if it is necessary to leave the wafer clean but wet with deionized water, and polishing using the mechanical pad 32 with the deionized water can take place. Thereafter, after lifting the wafer off the pad 32, spin drying of the wafer on the rotating wafer head assembly 12 can take place.

In operation, it will be appreciated that the belt-shaped mechanical pad 212 polishes the wafer similar to the manner in which a roller paintbrush paints a wall. While operating, the electrolyte or other solution is introduced to the mechanical pad 212 from a reservoir (not shown) located in proximity to the anode 214. In one specific embodiment, the anode 214 contains an in-channel 224 that includes a passageway 226 within anode 214 and holes 228 that are made in the anode 214, which together provide a path for the solution to be fed to the mechanical pad 212. Alternatively, the electrolyte solution can be dispensed directly onto the pad 212 through a channel 213 in accordance with the methods described earlier herein. The solution will be contained within a non-conductive chamber 230 that is created around the wafer head assembly 240, and a non-conductive solution containment housing 250, which housing contains an out-channel 252. O-rings and other conventional structures, as described earlier herein, to seal the solution within the solution containment housing 250 may be used in this embodiment.

Again, the electrochemical mechanical deposition apparatus according to the present invention reduces the need for pulse generating power supplies because the mechanical pulsing that is generated from the rotating movement of the pad and wafer creates sufficient pulsing.

According to the present invention, in any of the embodiments, since mechanical action is used to prevent undesired build-up of a conductor on undesired areas of a wafer surface, leveling agents are not typically needed, or needed in a much smaller percentage than conventionally used. Further a polished smooth and shiny conductive surface can be obtained.

Although only the above embodiments have been described in detail above, those skilled in the art will readily appreciate that many modifications of the exemplary embodiment are possible without materially departing from the novel teachings and advantages of this invention.

11. A method of depositing a conductive material from an electrolyte solution on a wafer, the method comprising the steps of:

applying a potential difference between the wafer and an anode having a pad attached thereto, the wafer being positioned in proximity to the anode, thereby causing the application of the conductive material to at least a portion of the wafer; and

minimizing accumulation of the conductive material to another area of the wafer different from the portion by polishing the another area with the pad while the step of applying the conductive material is being performed.

12. The method according to claim 11, wherein the conductive material comprises copper.

13. The method according to claim 11, wherein the portion of the wafer is below a top surface of the wafer and the another area of the wafer different from the portion is the top surface of the wafer.

14. The method according to claim 11, wherein the step of applying the conductive material further comprises the step of moving the pad that is attached to the anode and contacts the wafer to assist in retaining the electrolyte solution in contact with the portion of the wafer.

15. The method according to claim 14, wherein the step of moving the pad also minimizes accumulation of the conductive material to the another area.

16. The method according to claim 14, wherein the step of moving the pad also generates mechanical pulsing, thereby improving grain size.

17. The method according to claim 11, wherein the step of applying the conductive material further comprises the step of flowing the electrolyte solution through the anode and the pad.

18. The method according to claim 11, wherein the step of applying the conductive material further comprises the step of dispensing the electrolyte solution directly to the pad.

19. The method according to claim 11, wherein the step of minimizing accumulation prevents the conductive material from being formed on the another area of the wafer.

20. The method according to claim 11, wherein the step of applying, the potential difference applies the potential difference having a first polarity, and further including the following steps prior to the step of applying:

applying a second potential difference having a second polarity opposite the first polarity between the wafer and the anode having the pad attached thereto; and

polishing the wafer while applying the second potential difference.

21. A method of transferring an electrolyte solution containing a conductive material to a workpiece surface so that depositing of the conductive material can occur upon application of power, the method comprising the steps of:

placing a pad in contact with the workpiece surface; and

31. The apparatus according to claim 24, further comprising:

a workpiece head assembly adapted to support the workpiece and adapted to rotate the workpiece about a first axis; and

a pad assembly including the pad and the anode, the pad being movable with respect to the workpiece to assist in retaining the electrolyte solution in contact with the portion of the workpiece.

32. The apparatus according to claim 31, wherein the workpiece head assembly includes a resting pad and a retaining ring adapted to sustain the workpiece during the rotation of the workpiece.

33. The apparatus according to claim 24, wherein the chamber comprises:

an in-channel for flowing the electrolyte solution to the workpiece; and

an out-channel for flowing out the electrolyte solution from the chamber.

34. The apparatus according to claim 33 further comprising a resuscitating reservoir for replenishing and cleaning the electrolyte solution that is flowing out through the out-channel.

35. The apparatus according to claim 33, wherein the electrolyte solution is flowed from the in-channel through the anode and the pad to the workpiece.

36. The apparatus according to claim 33, wherein the electrolyte solution is flowed from the in-channel directly to the pad to the workpiece.

37. The apparatus according to claim 24, further comprising:

a workpiece head assembly adapted to support the workpiece, the workpiece being stationary;

a pad assembly having the pad attached to the anode; and

a shaft connected to the anode, the shaft adapted to rotate about a first axis, thereby causing the anode and the pad to rotate about the first axis.

38. The apparatus according to claim 24, further comprising:

a workpiece head assembly adapted to support the workpiece, the workpiece being adapted to rotate about a first axis;

a pad assembly having the pad attached to the anode, the anode being cylindrical and adapted to rotate about a second axis.

39. The apparatus according to claim 38, wherein the cylindrical anode includes a passageway and a plurality of holes, wherein the electrolyte solution is flowed to the workpiece through the passageway and the plurality of holes via the pad.

40. The apparatus according to claim 38, wherein the electrolyte solution is flowed from an in-channel directly to the pad.

41. An apparatus for simultaneously depositing a conductive material from an electrolyte solution to a portion of a workpiece and minimizing accumulation of the conductive material to another area of the workpiece, the apparatus comprising:

applying a second potential difference having a first polarity between the wafer and an anode having a pad attached thereto;

polishing the wafer while applying the second potential difference;

applying a first potential difference having a second polarity opposite the first polarity between the wafer and the anode having the pad attached thereto, the wafer being positioned in proximity to the anode, thereby causing the application of the conductive material to at least a portion of the wafer; and

minimizing accumulation of the conductive material to another area of the wafer different from the portion by polishing the another area with the pad while the step of applying the conductive material is being performed.

51. The method according to claim 50, wherein the another area is a top surface of the wafer and the portion of the wafer to which the conductive material is applied is below the top surface of the wafer.

52. The method according to claim 50, wherein the step of applying the conductive material further comprises the step of flowing the electrolyte solution through the anode and the pad.

53. The method according to claim 50, wherein the step of applying the conductive material further comprises the step of dispensing the electrolyte solution directly to the pad.

54. A method of depositing a conductive material from an electrolyte solution to a workpiece, the method comprising the steps of:

applying the conductive material to the workpiece using the electrolyte solution disposed on a surface of the workpiece, the workpiece being positioned in proximity to an anode; and

polishing the workpiece while the step of applying the conductive material is being performed.

55. The method according to claim 54, wherein the step of applying the conductive material further comprises the steps of moving a pad that is attached to the anode and contacts the workpiece to assist in retaining the electrolyte solution in contact with the workpiece and applying a current between the anode and the workpiece so that ionization will occur, thereby resulting in the deposition of the conductive material to the workpiece.

56. The method according to claim 55, wherein the step of moving the pad also polishes the workpiece.

57. The method according to claim 55, wherein the step of applying the conductive material further comprises the step of flowing the electrolyte solution through the anode and the pad.

58. The method according to claim 55, wherein the step of applying the conductive material further comprises the step of dispensing the electrolyte solution directly to the pad.

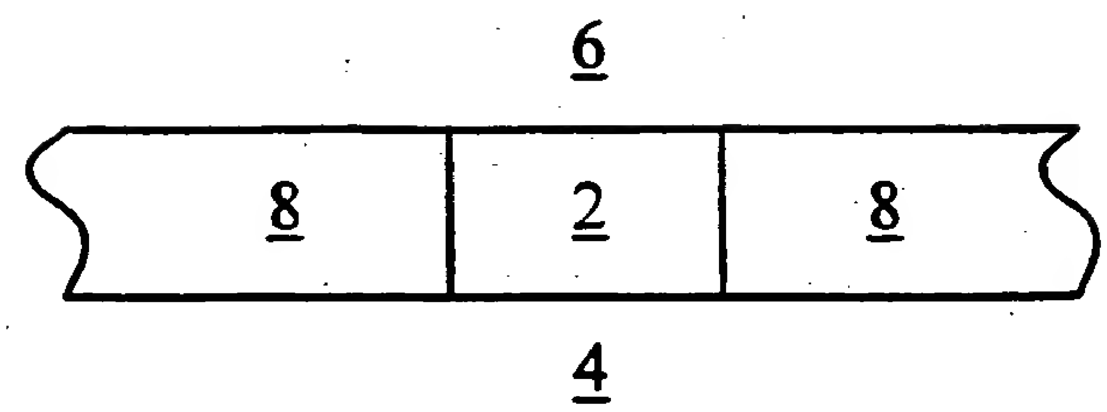

FIG. 3

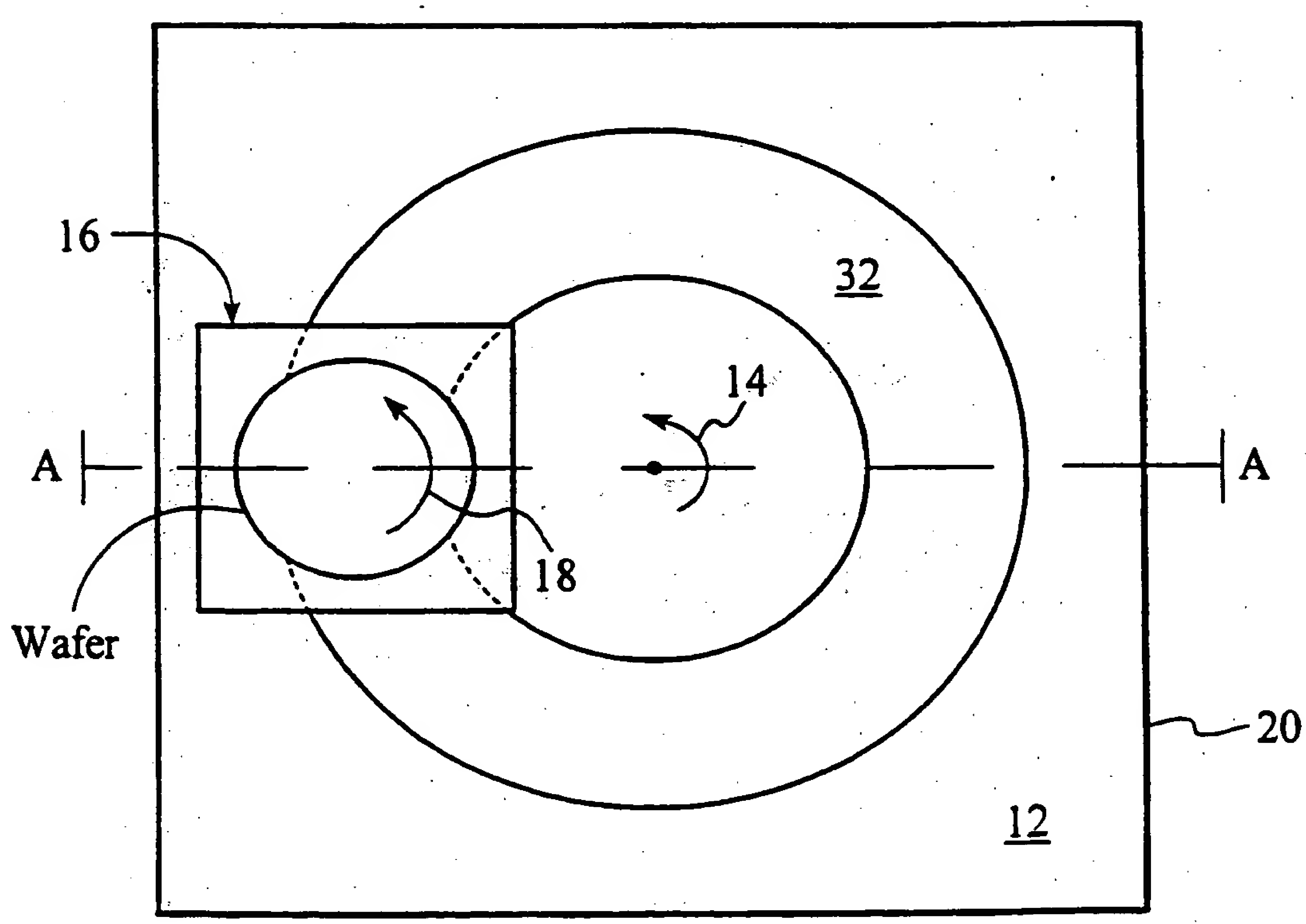

FIG. 1A

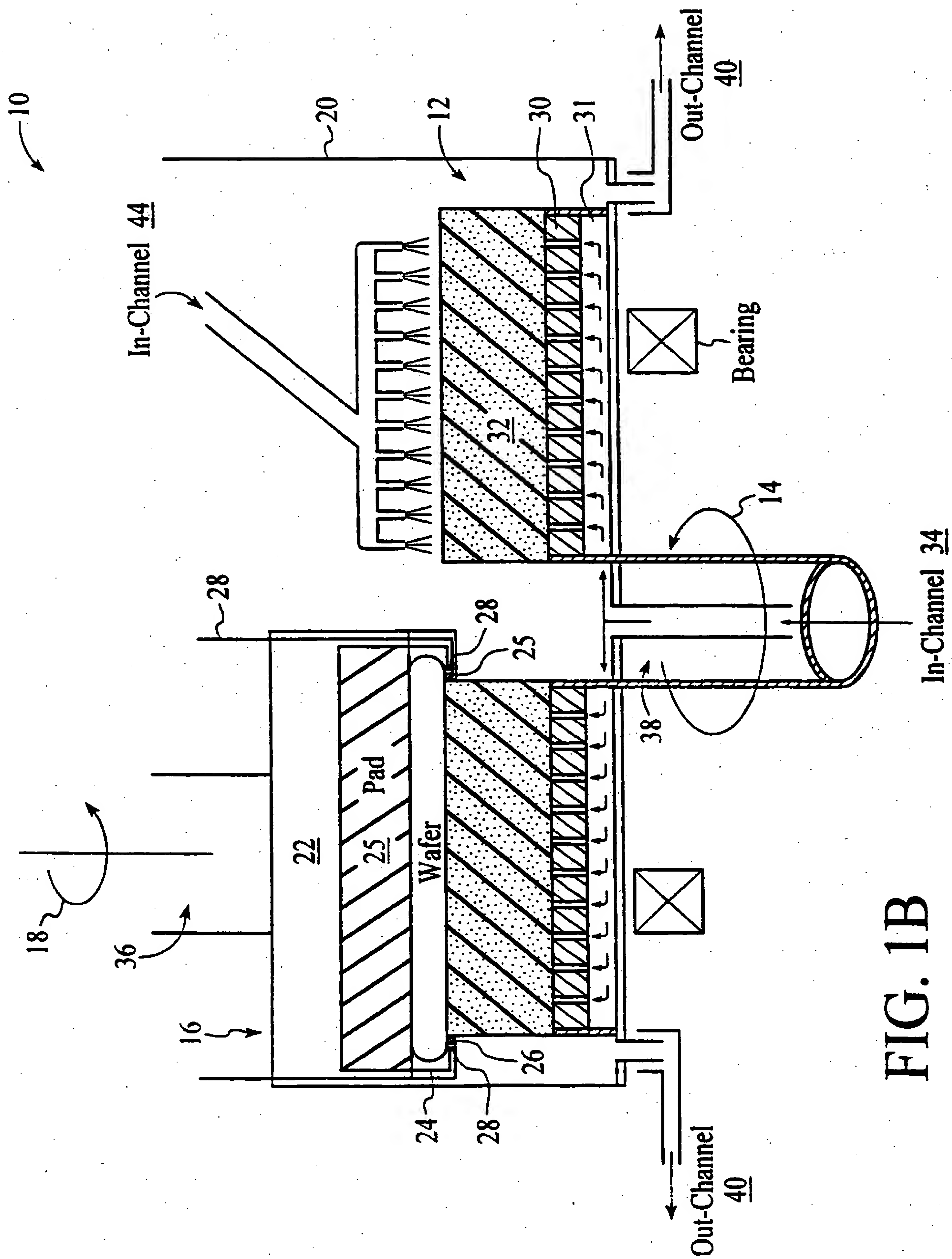
10
20
12
30
31
Out-Channel 40
In-Channel 44
Bearing
32
14
In-Channel 34
28
28
25
38
Pad
22
25
Wafer
18
36
16
26
24
28
Out-Channel 40

FIG. 1B

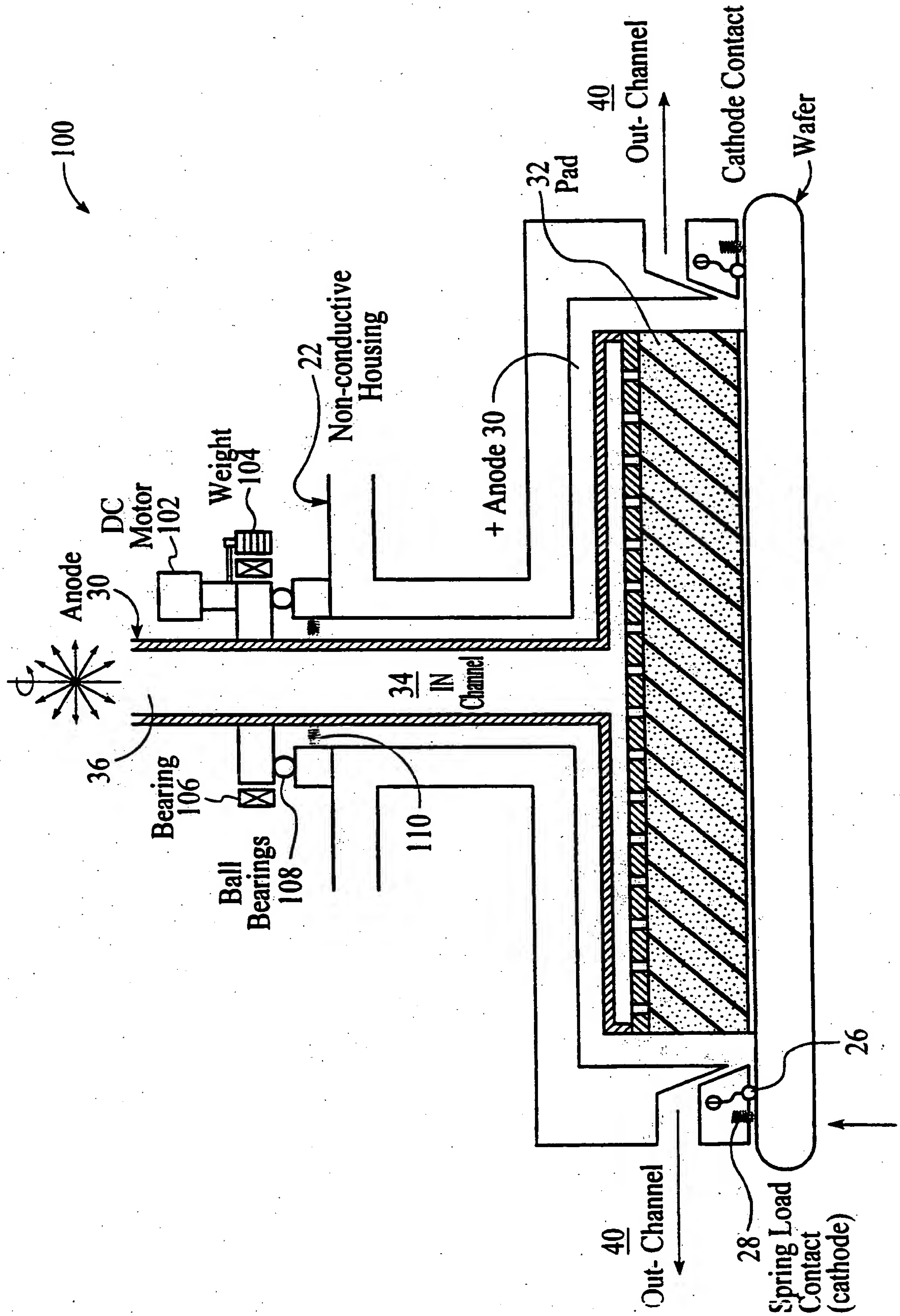
100
Anode 30
DC Motor 102
Weight 104
22 Non-conductive Housing
+ Anode 30
32 Pad
40 Out- Channel
Cathode Contact
Wafer
34 IN Channel
36
Bearing 106
Ball Bearings 108
110
26
40 Out- Channel
28 Spring Load Contact (cathode)

FIG. 2

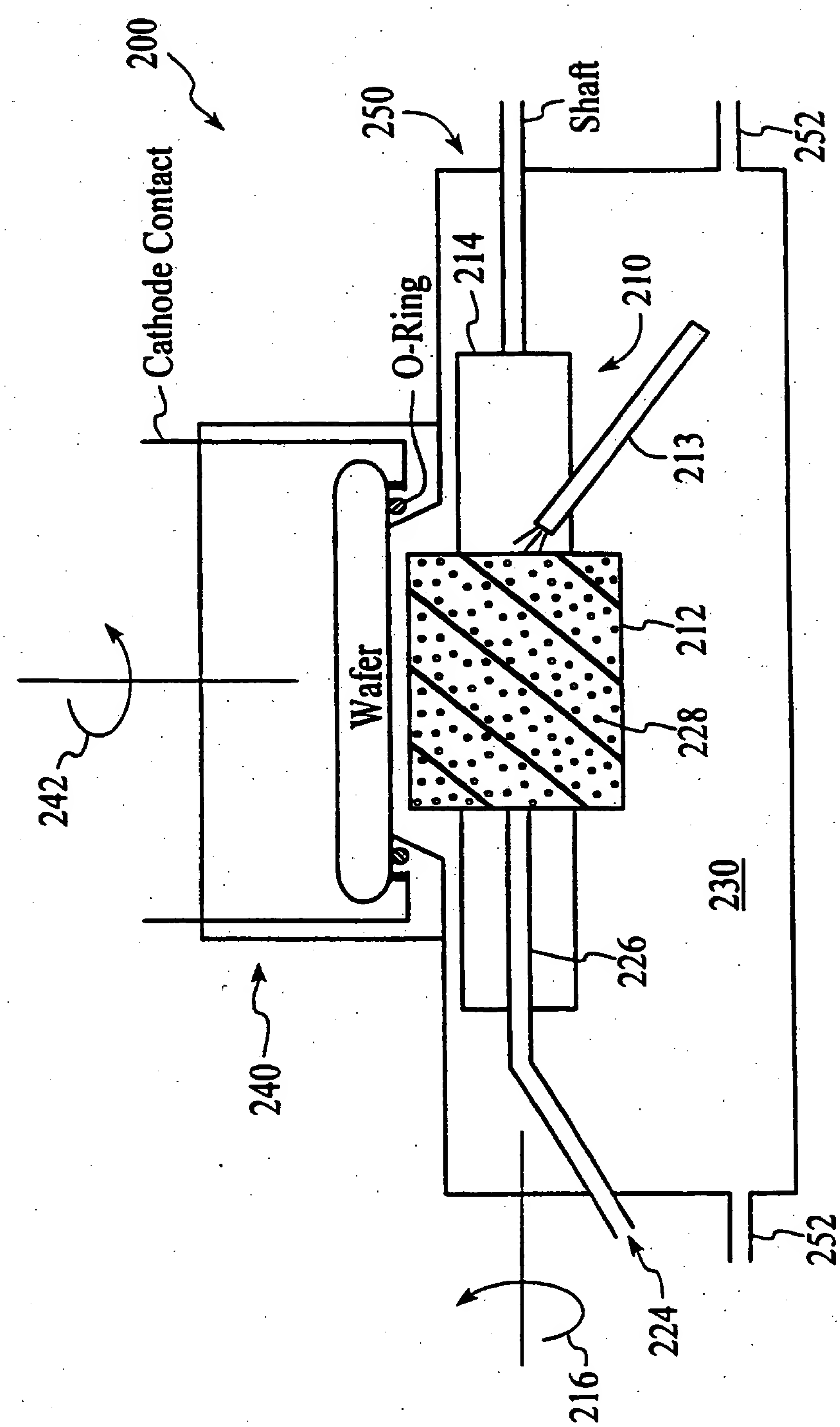
200
250
Shaft
252
Cathode Contact
O-Ring
214
210
213
212
228
Wafer
242
230
226
240
252
224
216

FIG. 4A

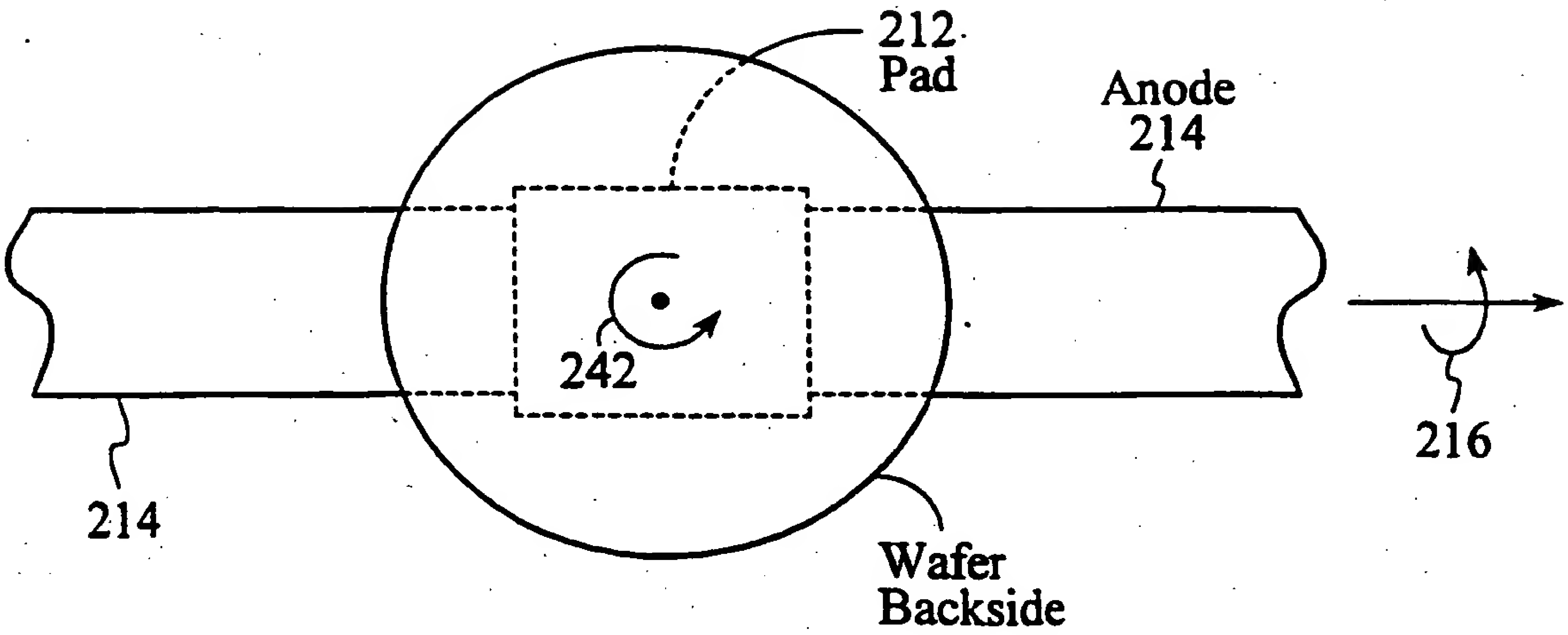
212
Pad
Anode
214
242
216
214
Wafer
Backside

FIG. 4B

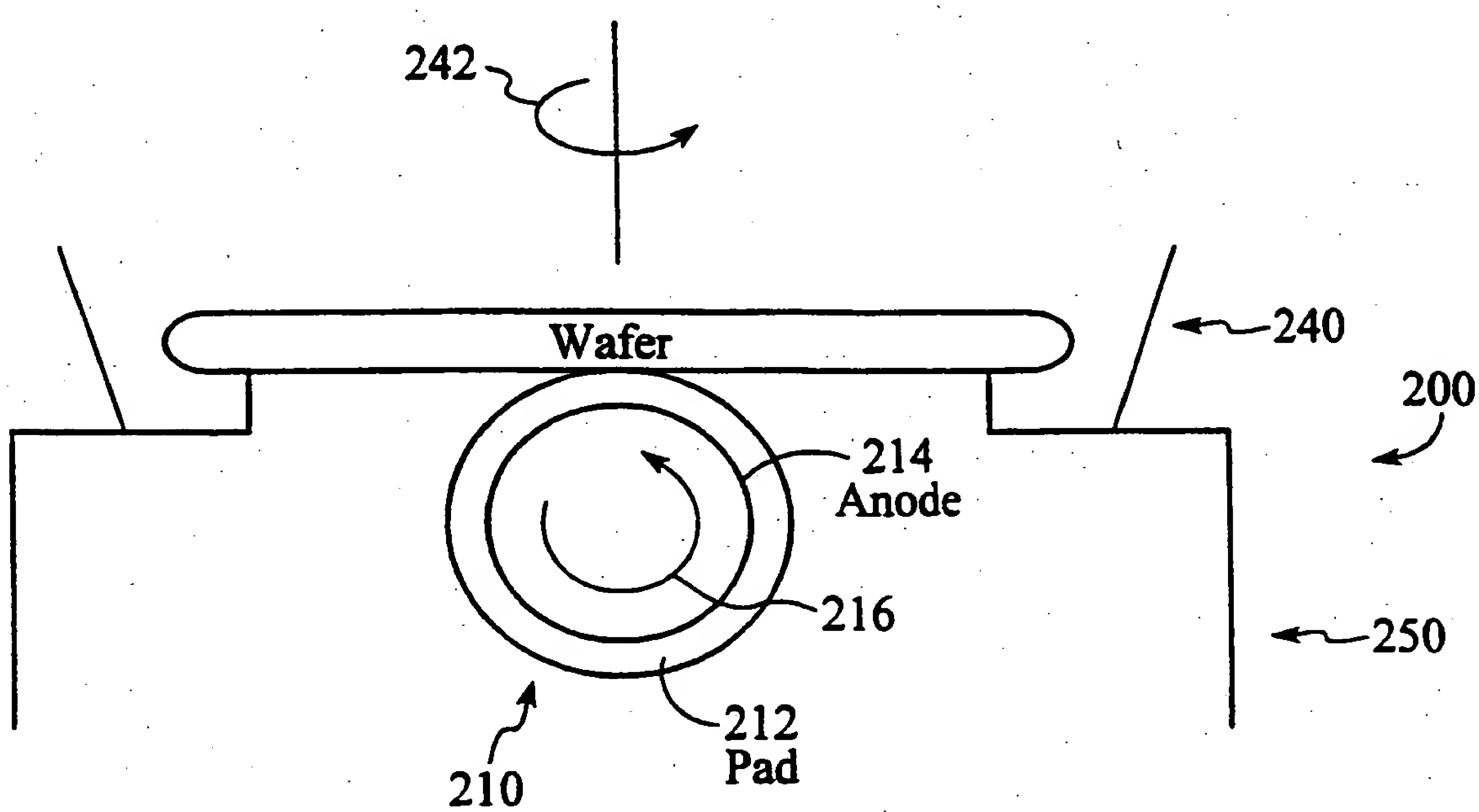
242
Wafer
240
200
214
Anode
216
250
212
Pad
210

FIG. 4C